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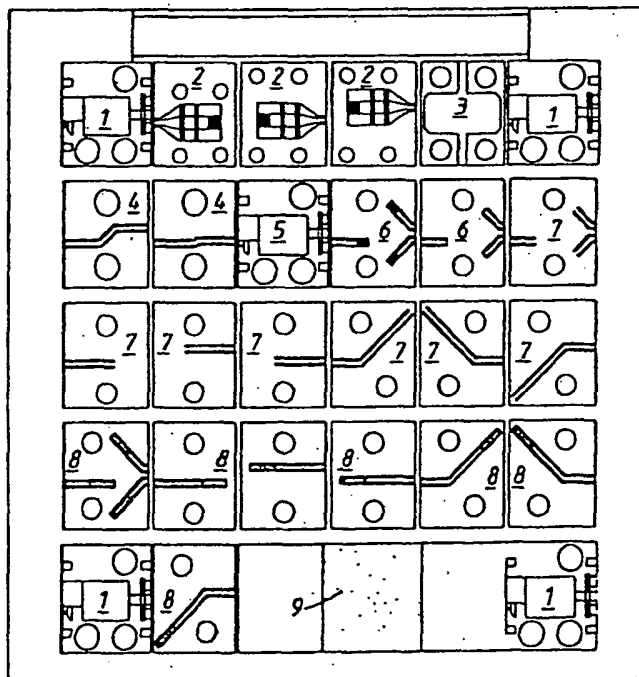
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## (54) Calibrating microwave integrated circuit test systems

(57) Apparatus for calibrating an integrated circuit test system comprises a substrate having a substantially planar array of thin film components (1-9) formed thereon. The components are provided with contact pads which have a spacing which enable the components to be engaged by the tip of a coplanar waveguide probe of the test system. The components may include 50Ω terminations, distribution matched loads, short circuits, through-lines, mismatch terminations, offset shorts and opens and test cells.

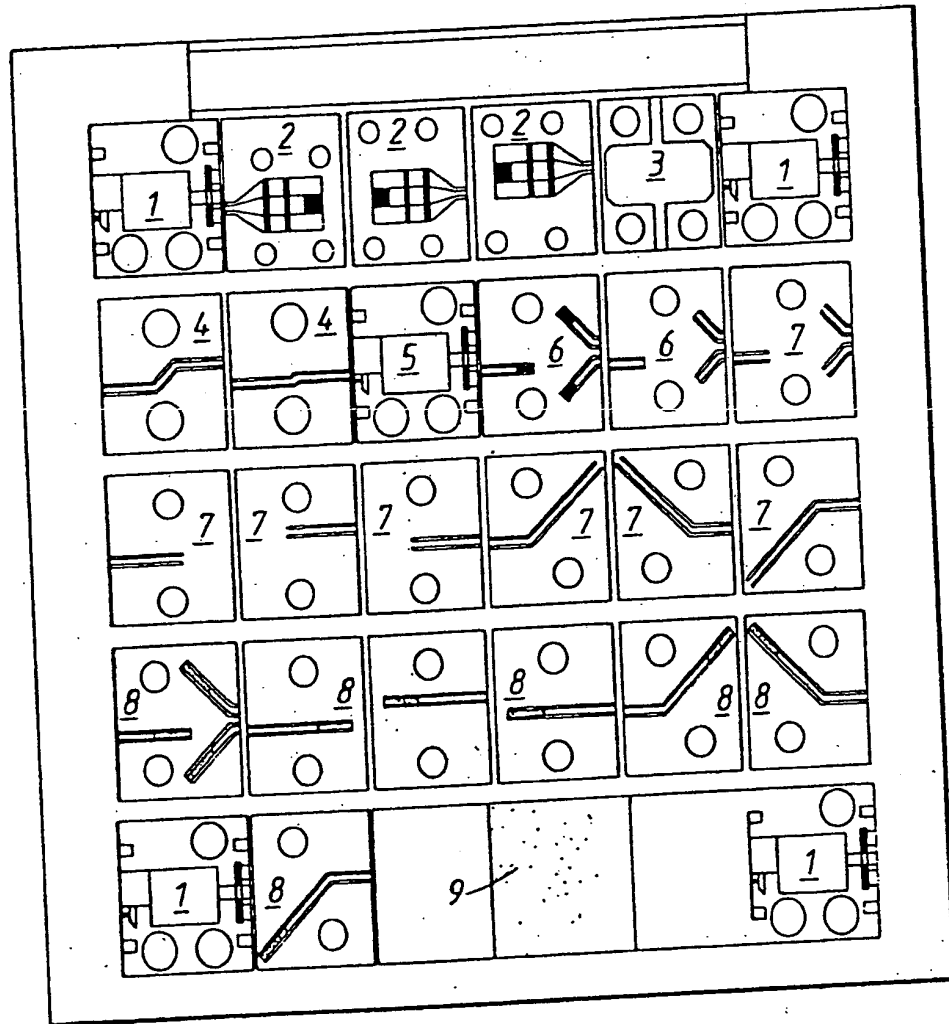
Such apparatus permits error correction under computer control and scatter parameter measurements with reference planes at the tips of the probe, obviating the need for de-embedding techniques.



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## SPECIFICATION

## Calibration apparatus for integrated circuits

- 5 The present invention relates to calibration apparatus for the automated on-wafer testing of integrated circuits and in particular for the automated on-wafer testing of Gallium Arsenide (Ga As) integrated circuits.
- 10 In order to minimise costs and timescales in the production of monolithic microwave integrated circuits, it is desirable to measure the microwave performance of an integrated circuit (IC) on-wafer prior to dicing the wafer into
- 15 individual chips. A means of transferring the microwave signals from the coaxial media of the test equipments to the coplanar medium of the IC radio frequency connecting pads by low-loss, low voltage standing wave ratio
- 20 (VSWR) probes is described in UK patent application No. 8511169, the contents of which is specifically incorporated herein by reference. The usefulness of such probe systems, however, is dependent on the accuracy of the
- 25 measurements made and, to minimise errors, it is necessary to obtain a means of calibration for the test equipment used.

- For simple gain and power measurements it is possible to characterise the probes and
- 30 feeds from the test equipment for insertion loss and use this information to compensate the actual results obtained. For sensitive vector S-parameter (scatter-parameter) measurements, however, a more precise model of the
- 35 imperfections between the test equipment and the device under test must be determined.

- Network analysis in a coaxial or waveguide medium is, conventionally, achieved by using a wide range of calibration and verification components. By measuring a variety of such components, e.g. matched load, short circuit, open circuit etc., it is possible to construct error models for the measurement ports and thus remove the error terms from subsequent measurements. This technique is known as
- 40 8 to 12 term error and is described in "Error Models for Systems Measurements", Microwave Journal, May 1978 by J. Fitzpatrick. However, no such components are available
- 50 for variable geometry microwave probe measurements and furthermore, such components would not permit an automated calibration/test procedure to be achieved, resulting in higher production costs of the devices under
- 55 test.

- It is an object of the present invention to provide apparatus for enabling grounded coplanar waveguide calibration of integrated circuit test equipment whereby the grounded coplanar probes used to measure the parameters of an integrated circuit under test can be utilised in the procedure for calibrating the test

the apparatus comprising a substrate having a substantially planar array of thin film components formed thereon, at least one of the components having contact pads arranged such that they can be engaged by a coplanar waveguide probe of the integrated circuit test system.

- 70 The substrate may comprise alumina and the thin film components may comprise a resistive layer having an overlay of metallised conductors.

- 75 The resistive layer may comprise nichrome and the metallised conductors may comprise gold.

- 80 The resistive layer may be deposited to a thickness to provide a sheet resistance of  $50\Omega$  per square for the resistive layer.

- Preferably, low inductance ground connections for the components are provided by via holes containing conductive material, such as conductive epoxy or metal.

- 85 The present invention will now be described by way of example, with reference to the accompanying drawings which illustrates an enlarged schematic plan view of apparatus in accordance with the present invention.

- Referring to the drawing, the thin film components 1 to 9 are formed on an alumina substrate, typically 1 inch square, with a thin resistive layer—NiCr for example—and plated gold conductors. The resistive layer is deposited to a thickness which provides sheet resistance of  $50\Omega$  per square. In the example shown the components 1 to 9 comprise as follows:—
- 100 (1)  $50\Omega$  terminations for alignment check;
- (2) Distribution matched loads incorporating pseudo T attenuators; as described by H.J. Finlay et al, "Design and application of precision microstrip multi-octave attenuators and loads" Proc. 6th European Microwave Conference, Rome 1976.
- 105 (3) Short circuits;
- (4) Through lines; to provide  $50\Omega$  transmission lines;
- 110 (5)  $50\Omega$  terminations for isolation measurement, to permit termination of both probes used in the IC test procedure simultaneously.
- (6) Mismatch terminations;
- (7) Offset short circuits; low inductance short circuits displaced by a length of  $50\Omega$  transmission line;
- 115 (8) Offset open circuits; low inductance open circuits displaced by a length of  $50\Omega$  transmission line;
- 120 (9) Large test cell to determine sheet resistivity;

- The components 1 to 9 achieve low inductance local grounding by the use of via holes which may be filled with conductive material, such as conductive epoxy or metal or a metal plating on the wall of the via holes.

The components are arranged to have the

and to permit auto-stepped execution of the calibration procedure. The particular example illustrated is designed for an IC having one input and two output RF ports, but other designs may be used for alternative input/output port combinations.

Calibration using such as substrate allows the use of error correction under computer control resulting in S-parameter measurements with reference planes at the probe tips, i.e. the IC RF contact pads. This removes the need for sophisticated but error-prone de-embedding techniques and is particularly valuable in individual IC component element characterisation.

Furthermore, the use of integrated calibration components as described above facilitates and enhances the quality of measurements made using the microwave probe system thereby providing a valuable tool in monolithic microwave circuit production.

It can be seen, therefore, that considerable advantages can be achieved with the apparatus of the present invention, leading to low unit cost for the tested IC components.

Although the present invention has been described with respect to a particular embodiment it should be understood that modification may be effected within the scope of the invention.

#### CLAIMS

1. Apparatus for calibrating an integrated circuit test system, the apparatus comprising a substrate having a substantially planar array of thin film components formed thereon, at least one of the components having contact pads arranged such that they can be engaged by a coplanar waveguide probe of the integrated circuit test system.

2. Apparatus according to claim 1 wherein the substrate comprises alumina and the thin film components comprise a resistive layer having an overlay of metallised conductors.

3. Apparatus according to claim 2 wherein the resistive layer comprises nichrome.

4. Apparatus according to claim 2 or claim 3 wherein the metallised conductors comprise gold.

5. Apparatus according to any one of claims 2 to 4 wherein the resistive layer is arranged to have a thickness for providing a sheet resistance of  $50\Omega$  per square for the resistive layer.

6. Apparatus according to any one of the preceding claims comprising via holes containing electrically conductive material for providing low inductance ground connections for the thin film components of the array.

7. Apparatus according to claim 6 wherein the electrically conductive material comprises conductive epoxy.

8. Apparatus according to claim 6 wherein the electrically conductive material comprises metal.

9. Apparatus according to any one of the preceding claims wherein the thin film components comprise, in any combination, a  $50\Omega$  termination for alignment check, a distribution matched load incorporating a pseudo-T attenuator, a short circuit, a through line for simulating a  $50\Omega$  transmission line, a  $50\Omega$  termination for isolation measurement, a mismatch termination, an offset short circuit, an offset open circuit and a large test cell for determining the sheet resistivity of the apparatus.

10. Apparatus for calibrating an integrated circuit test system substantially as hereinbefore described with reference to the accompanying drawing.

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